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Point contact Josephson junctions

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SUMMARY

A description is given of relatively high impedance (10 - 1000 Ω) superconducting niobium point contact Josephson junctions, which can be used as wide-band detectors of millimeter and submillimeter radiation. The antenna characteristics of the employed structure are discussed and have typical impedance values of the order of 100 Ω. Using a burn-in method the junction resistance can be approximately matched, so that these junctions couple optimally to external radiation. As a result of an electropolishing treatment and the burn-in process, these junctions are mechanically and electrically stable at 4.2 K.

The quality of the junctions, that can be expressed by the product of the maximum possible supercurrent I_c and the normal state resistance R, has been gradually improved. At this moment $I_cR \sim$ 1300 μV which is about 2/3 of the theoretical maximum value. A review of the theory on wide-band detection shows that fortunately resistance values of about 100 Ω are also optimum to achieve a maximum responsitivity to external radiation and a minimum 'noise equivalent power' (NEP).

Using a Michelson interferometer the spectral response has been determined for several resistance values as a function of the frequency of external radiation ($\sim$ 300 GHz). The resistance has been decreased more or less continuously by controlling the burn-in process. A strongly peaked response is found with a bandwidth of about 40 GHz, in quantitative agreement with earlier estimates based on the antenna theory.

The frequency of maximum response ν_r, however, cannot be related to antenna resonance frequencies. On the other hand, the change of ν_r with the junction resistance R can be explained by the Josephson effect itself. In underdamped junctions the supercurrent state is unstable with regard to phase oscillations, induced by external radiation, at a frequency equal to the plasma frequency (plasma oscillation of Cooper pairs). It is shown that this frequency $\nu \propto R^{-1/3}$. This corresponds with the experimentally found relation between ν_r and R, if R is so high that the junction is underdamped. The response peaks for $R \simeq 100\ \Omega$ at $\nu_r \simeq 150$ GHz. Used as a wide band detector, the minimum detectable temperature difference of the detector is estimated to be $\Delta T \simeq 5 \times 10^{-3}$ K corresponding to a NEP $\simeq 3 \times 10^{-15}$ W/Hz$^{\frac{1}{2}}$, at $\nu \simeq 150$ GHz.